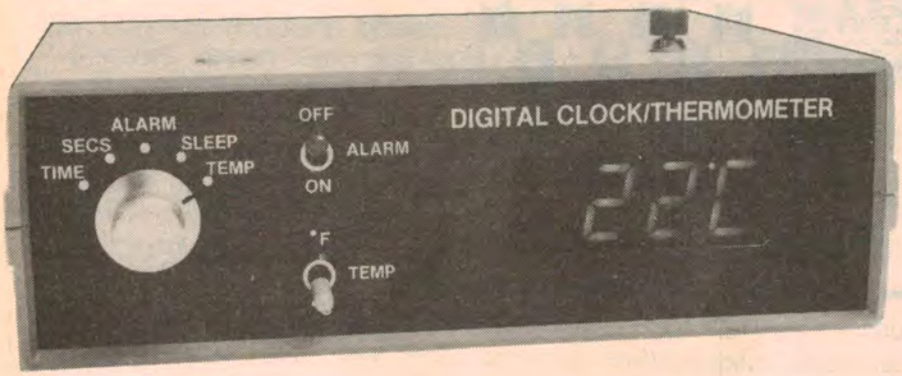
Tired of squinting at the mercury? Then rest your eyeballs on this!

# Digital Clock and Thermometer

Many of our readers have requested this project — a digital thermometer with big bright display. But you also get a bonus 4-digit clock with alarm and more features than you can poke a stick at. It is based on a National Semiconductor module in which the IC chips are bonded directly to a PC board which carries the LED display and other components.




Let's face it, mercury or alcohol thermometers are not easy to read or use. A digital thermometer with a big bright readout has quite a few applications in the home, workshop and laboratory.

In the home, our digital thermometer can be used to keep a check on inside and outside temperatures, on your freezer and refrigerator and the temperature of tropical fish tanks. In the photographic darkroom, it can keep track of temperatures in developing tanks while in the laboratory and workshop the applications become wider still – measure heatsink or motor temperatures, etching baths and so on. In fact, the only limit is the number of temperature sensors you use and the overall permissible temperature range of −40°C to +89°C.

You can build this thermometer/clock (or clock/thermometer, which is easier to say) in a variety of forms. You can "go the whole hog" as we did and end up with a handsome but quite expensive unit which really looks the part and provides a lot of functions. Or you can forego some of the functions, put it in a less expensive case and save quite a lot of money.

## THE CIRCUIT

Heart of the circuit is the MA1026 "Digital LED Alarm Clock/Thermometer Module" recently released by National Semiconductor. It requires only a handful of external components to produce a finished, working project; in particular, a power supply, function and time-setting switches and temperature sensors.

The MA1026 is a hybrid PC board-cum-integrated circuit. The board measures just 95 × 45mm. On one side it has two dual-digit LED displays while on the other it has components for the power supply, a number of transistors plus a few capacitors and resistors. It also has two IC chips which are bonded and terminated directly to the PC tracks. The main chip is roughtly 4mm square and covered with a blob of encapsulation under which a maze of leads can be seen terminating to the chip. There are 58 leads in all, which would make a large IC if housed in a conventional in-line package.

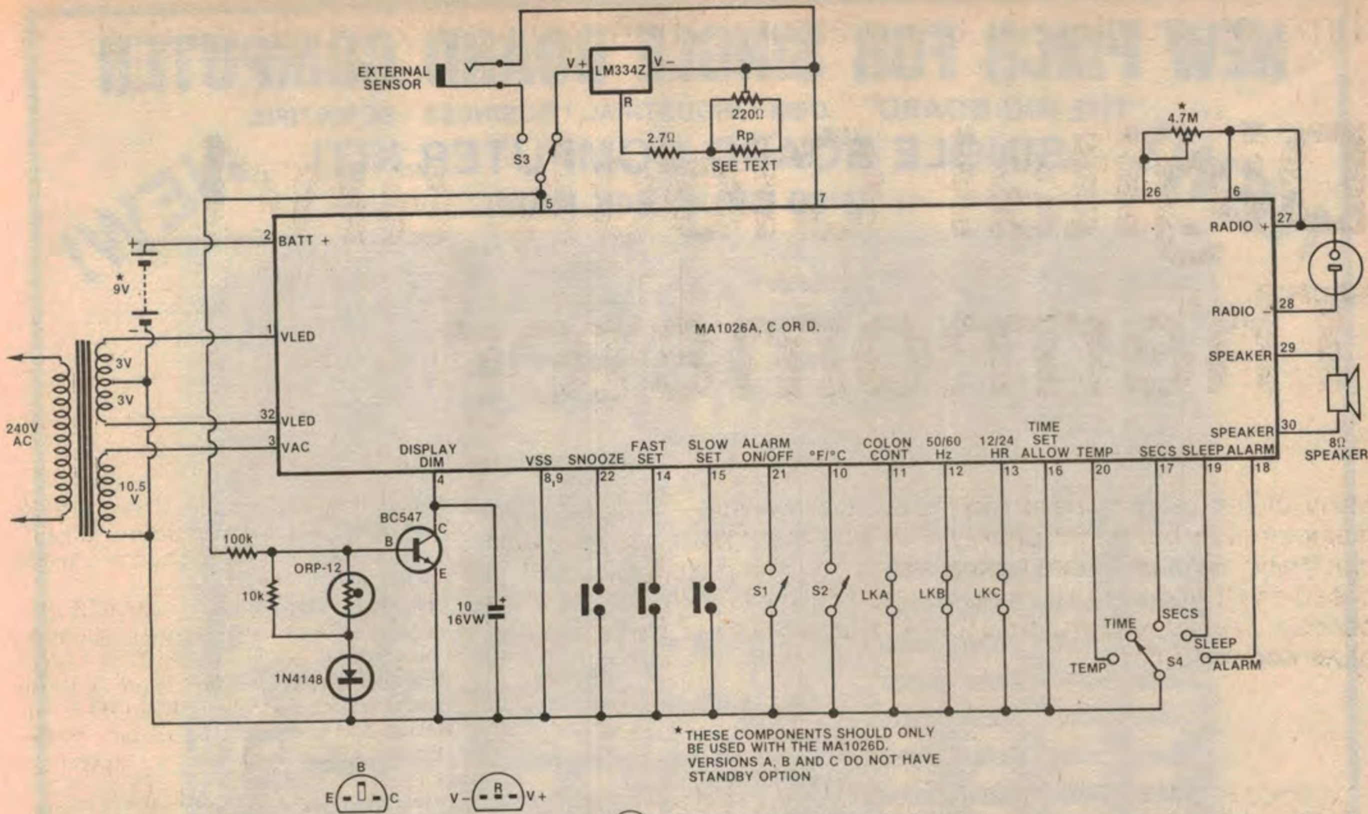
Like most clock chips, the MA1026 provides a list of optional features as long as your arm and which would take a great deal of space to describe in full. We will describe those which are featured in our design and briefly allude to some of the others which may be of interest to readers.

The main chip on the MA1026 module is virtually a conventional clock chip with some extra internal circuitry allowing it to display temperature values. Thirty-one of the chip pins drive the LED display from rectified but unfiltered DC while 12 control pins provide normal clock features with each pin pulled low to enable that particular feature. The controls are listed as follows: Colon control (low to stop 1Hz flashing), 50/60Hz select (low for 50Hz), 12/24 hour select (low for 24Hr which disables PM indication), Alarm off, Time Set Enable, Fast Set, Slow Set, Display Seconds, Display Alarm, Snooze and Brightness.

Two control pins provide the temperature display facility: Display Temp and Fahrenheit/Celsius select (low for Celsius), The remaining pins on the clock chip are for connection of supplies, temperature interface circuitry and the three control outputs: Alarm, Sleep and 24Hr.

Additional circuitry on the MA1026 module provides temperature input data from external sensors. The temperature sensor used is the LM334, made by National Semiconductor, who describe it as a three-terminal adjustable current source. National Semiconductor has made use of the temperature coefficient of current in this application. For the LM334, the output current increases by one microamp for every one Celsius degree rise in temperature.

When the current from the LM334 is applied to a 10kΩ resistor (on the module) the resulting voltage increases by 10 millivolts for every one Celsius degree rise in temperature. This is converted to a frequency signal which can be displayed by the clock chip counters in Fahrenheit or Celsius.



DIGITAL THERMOMETER/CLOCK

*The circuit of our prototype may be modified to suit readers' individual needs. For example, S3 could be replaced by a multi-position switch to accommodate more temperature sensors. Note that each sensor requires its own resistor trimming network and each of these must be adjusted against a reference thermometer.*

We should add, at this point, that the LM334 is guaranteed for accuracy only over the range from 0°C to 70°C. In order to guarantee accuracy and reliable operation over the full measurement range of the MA1026, we would have had to specify the more expensive LM134 which has an operating range of −55°C to +125°C or the LM234 which has an operating range of −25°C to 100°C (which would reduce the measurement range for very low temperatures). As it is, we feel that the LM334 will be satisfactory for most likely applications.

We have added several features to make the MA1026 even more attractive as a clock. First, we have added a back-up power supply which keeps the clock counters going in the event of a mains power failure – very handy in view of recent blackouts in NSW and Victoria. The back-up supply takes the form of a 9V battery which is normally isolated by a diode on the module. Some MA1026 modules may not have this diode and a capacitor necessary to run a standby back-up oscillator which drives the counters. We will talk about this aspect later.

The other feature we have added is a dimmer for the display. Many digital clocks with "fixed brilliance" displays are too bright at night (in darkness) or not sufficiently bright in rooms where there is a high level of ambient lighting. We have added an LDR circuit which automatically dims the display in darkness.

The LDR circuit consists of the LDR itself, two resistors, a capacitor and a transistor. A look at the circuit diagram will show how it is connected. The LDR is shunted by a 10kΩ resistor and then connected to ground via a diode. The other end of the LDR/resistor combination is connected to the base of an NPN transistor and one end of a 100kΩ resistor, the other end of which is connected to the positive DC supply from the module. The diode is used to keep the voltage at the base of the transistor in the region of the base-emitter conduction voltage, 0.6 volts.

The collector of the transistor is connected directly to the dimmer input (pin 4) on the clock module. A 4.3kΩ pullup resistor on the main clock chip normally maintains the display at full brightness. If the dimmer input is now taken low the display will dim. This is exactly what happens when little or no light falls on the LDR. Under bright lighting conditions, the resistance of the LDR will be very low relative to the 100kΩ resistor at the base. This will result in the transistor being turned off and the dimmer input rising to full supply voltage (due to the on-board pull-up resistor) to give full display brightness.

If the light level happens to fall, the resistance of the LDR will start to increase, resulting in a positive bias being applied to the base of the transistor. This will result in a collector current flowing, pulling the dimmer input down to a lower voltage. When the LDR has no light falling on it, the transistor will be turned on and the display will dim down to 25% of full brightness. The 10kΩ resistor in parallel with the LDR is used to linearise the response of the LDR to changing light conditions. The 10μF capacitor connected between the collector and ground is used to smooth the half-wave DC present at the dimmer input.

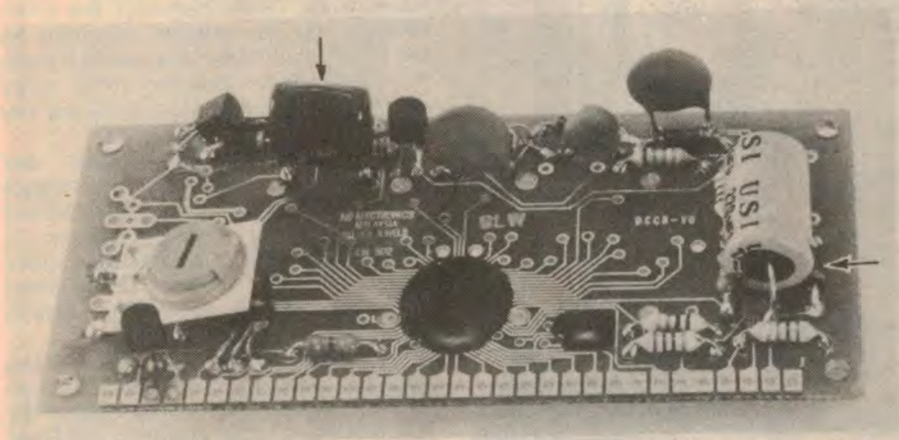
> We estimate that the current cost of parts for this project is approximately
>
> **$80.00**
>
> This includes sales tax.

## OUR PROTOTYPE

Our prototype unit was constructed in an attractive plastic case manufactured by Pac Tec of the US. This case is distributed in Australia by Associated Controls Pty Ltd and is available over the counter from Dick Smith Electronics.

The function select switch, the alarm on/off switch and the selection switch are all mounted on the front panel together with the clock module itself. The time-setting push buttons, temperature sensor changeover switch and remote sensor socket and the sleep timer output socket are all mounted on the rear panel.

Five display modes are selected by the rotary selector switch: time (hours and minutes) seconds, alarm time, sleep timer and temperature. A toggle switch is used to select between the two temperature scales while a second is us-



*The diode and capacitor arrowed must be added for the standby oscillator facility.*

ed for the alarm disable. A third toggle switch, located on the back panel, is used to select between the internal (rear-mounted) and an external temperature sensor.

The sleep function allows an external transistor radio to be used with the clock unit. The radio can be switched on as the alarm device at the alarm set time and can also be enabled by the sleep timer. The sleep timer is a counter that starts counting down from 59 minutes. When the sleep timer reaches zero, the radio is switched off.

The output for this function is in the form of an open-collector output, the emitter of the switching transistor being connected to the positive side of the clock supply. The positive of the clock supply is used as the common between the clock unit and an external radio, instead of the zero volts line.

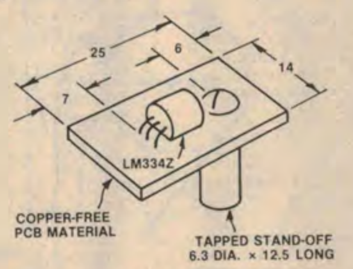
The MA1026 module has a time-set enable input but we decided not to make use of the feature and enabled it permanently instead. If desired a switch could be incorporated to disable the time setting mode. This is handy if you have inquisitive kids about the place who like to fiddle.

The LDR for the dimmer circuit and the snooze button have been mounted on the top of the case – the LDR so that it gets maximum exposure to ambient light, and the pushbutton so that it can be easily pressed to disable the alarm on a Monday morning.

The module is powered from a small transformer which has two secondary windings, one at 6V with a centre tap and the other at 10.5 volts. The 10.5 volt winding is used to power the clock chip and ancilliary circuitry while the six volt CT winding is used for powering the LED display and the alarm loudspeaker.

We have designed a printed circuit board on which all of the remaining components are mounted, including the power transformer. The board measures 172 × 120mm and is coded 81cl9. The board is larger in area than it really needs to be, but we have chosen this particular size to take advantage of the mounting locations in the base of the Pac Tec enclosure. This means that we have no screws showing through the bottom of the case – an advantage aesthetically and from a safety point of view.

We have also designed a front panel artwork for use with aluminium "Scotchcal" material for production of a suitable label. The artwork has been designed to be used with the Pac Tec




DIMENSIONS IN MILLIMETRES

*This diagram shows how to mount the sensor on the rear of the case.*

enclosure, but could be modified by the constructor if he opted to used a different type of enclosure.

As we remarked at the beginning of this article it is possible to build this project in a variety of forms. If you build it with all the features we have included and use the Pac Tec case the resulting unit will be relatively expensive but should give a lot of satisfaction as a "complete" project. On the other hand if you decide to make do without the Pac Tec case, front panel and dimmer facility you could also dispense with the PC board and save a substantial amount in total.

For example, you may wish to build a version which can display just the time and temperatures at five separate locations. This would require five LM334 sensors and their associated resistor network in each case plus a six-position, two-pole switch to perform the selection. The only other components required would be the MA1026 module itself, the transformer and two pushbutton switches for time-setting. Even the Fahrenheit/Celsius switch could be eliminated from such a basic version – just wire in a link for Celsius.

Alternatively, another possible version could provide just the time and alarm functions with, say, four temperature sensors. You would then require the parts mentioned previously plus a small speaker to sound the alarm (which is a pulsed 800Hz tone).

Let us now proceed to describe the construction of our prototype.

## CONSTRUCTION

Construction of the unit will take time since there is a lot of preparatory work to be done on the enclosure and then quite a lot of wiring.

The first step is to mount the components onto the printed circuit board. Note that these include the mains terminal block.

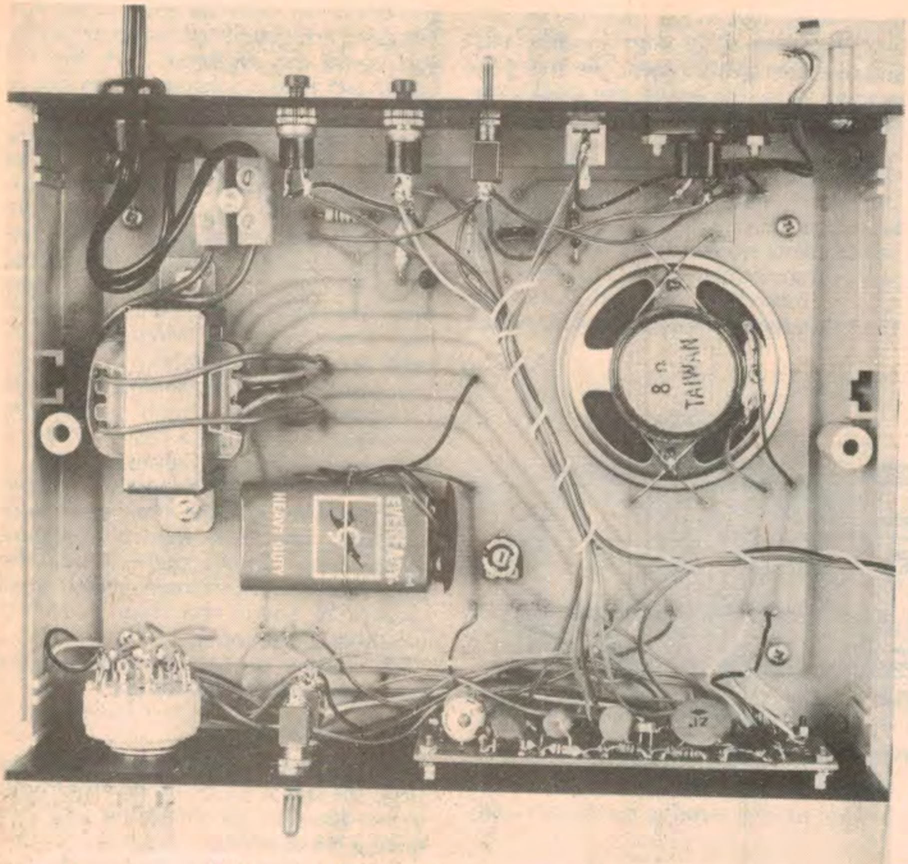
The use of PC stakes is recommended since they help in the final wiring operation.

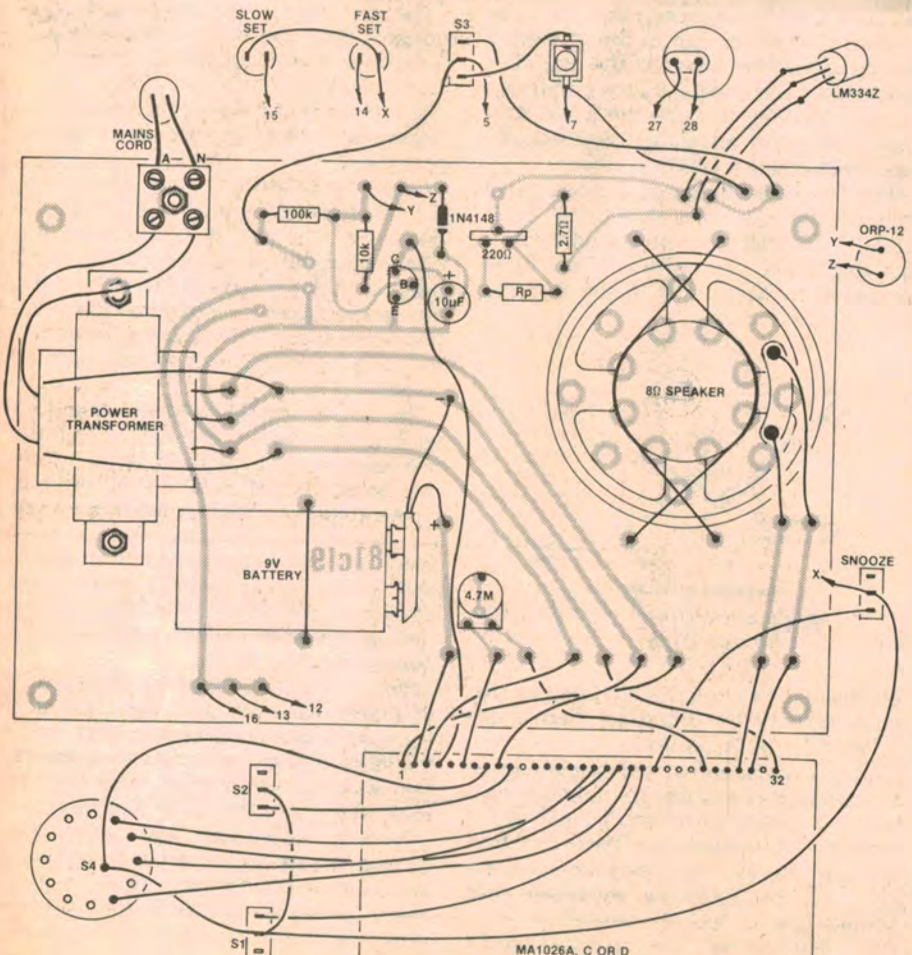
Once the board has been assembled, put it aside and start preparing the enclosure. This will involve cutting the opening for the LED displays of the clock module; drilling and countersinking the four screw holes for the module mounting screws; and drilling the other holes for the switches, pushbuttons and sockets.

The slot for the LED displays should be cut out next. Note that the module must be mounted onto the front panel before the Scotchcal label is affixed to the panel. In this way, the screws that secure the module to the panel are covered from view, resulting in a neat front panel. The small screws which secure the module to the panel should be countersunk so that they are flush with the panel when tightened down.

Once the module has been mounted you are ready to affix the Scotchcal aluminium label to the panel. First, spray the label with a clear lacquer for protection and then use a sharp razor knife to make the cut out area for the displays.

Carefully score the label along the cutout lines several times until the blade just starts to bite through. Now carefully apply pressure to the section to be removed. If the scoring is deep enough,






the aluminium will start to break away along the cut lines. If not score it a little more.

If the holes for the rotary switch and the two toggle switches were drilled prior to the label being stuck into place, then again, with the aid of a razor knife, carefully cut away the unwanted aluminium. Then strip away the label backing and affix to the case panel.

Now mount the rotary switch and the two toggle switches. The next step involves wiring up the connections that have to be made between the clock module and the switches mounted on the front panel. Once this part of the job has been done, put the front panel assembly aside and start work on the rear panel.

Mount the two pushbuttons, the double-pole, double-throw toggle switch and the two sockets onto the rear panel. The temperature sensor is mounted on the rear, but external to the case. A drawing showing a suggested mounting method appears elsewhere in the article.

Once the components have been mounted onto the rear panel we can turn our attention to the mounting of the LDR and the snooze button in the lid of the enclosure.

We mounted the LDR by drilling a hole in the lid and then carefully filing it until the body of the LDR was a tight fit in the hole. It was held in place using Aquadhere applied over the back of the body. (This glue takes a long time to dry in this application.)

The snooze button was mounted in the right hand top corner of the lid, an easily accessible place for the half awake.

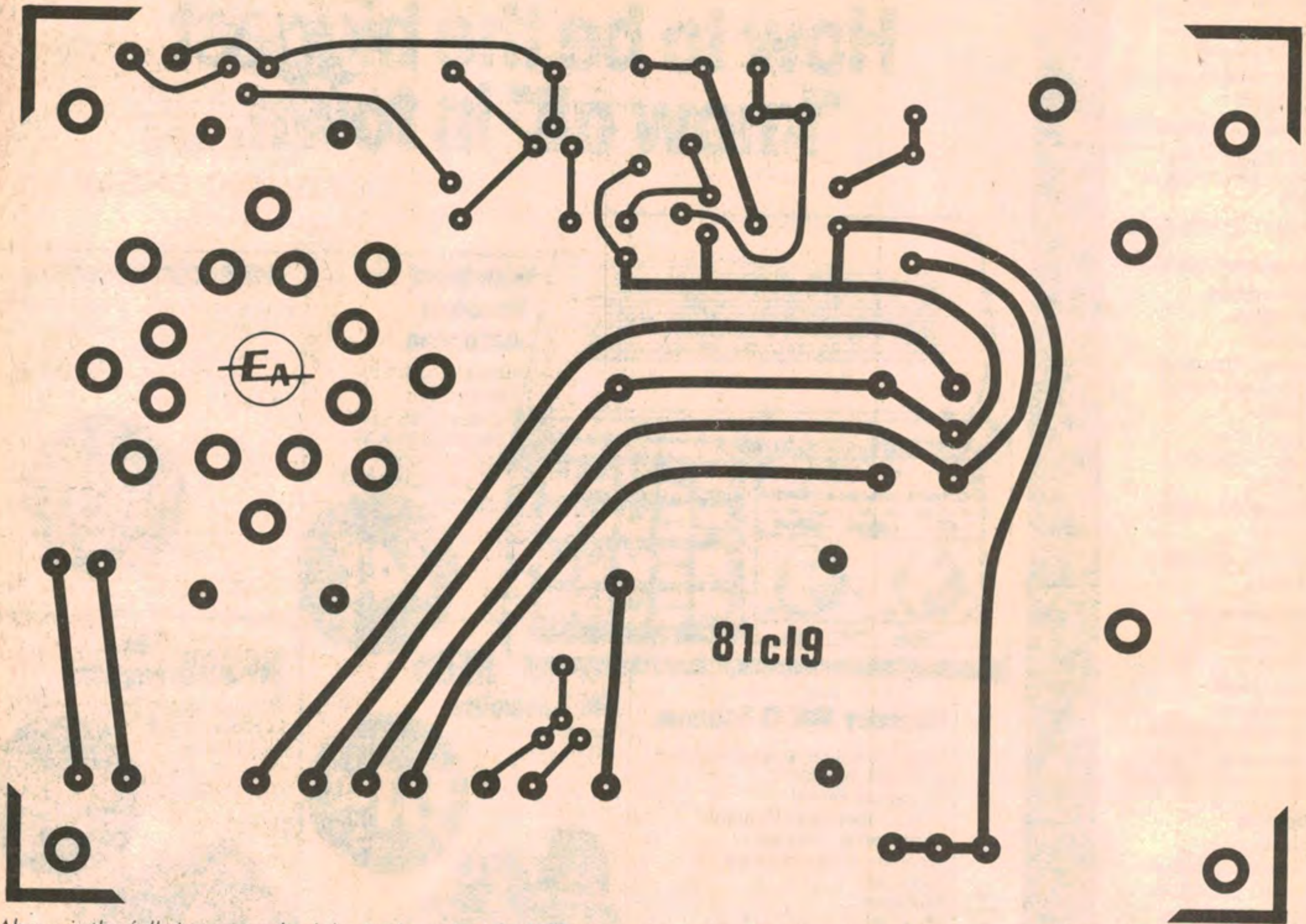
If you elect to use a metal case instead of the Pac Tec case, the mains terminal block should be mounted on the chassis rather than on the PC board and the earth wire in the three mains flex should be terminated to a solder lug secured by a screw and nut to the base of the case.

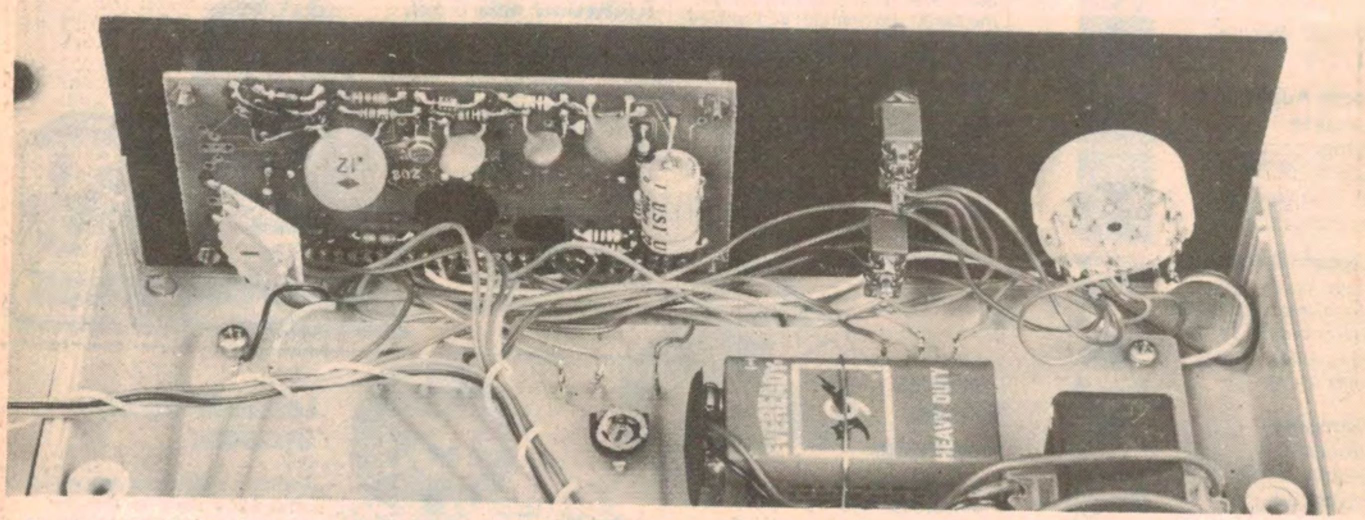
Once all of the mechanical work has been done (at least in terms of bolting things to panels) we can proceed with the remainder of the wiring.

The mains cable used in the prototype was clamped in place by using a cord grip clamp. These are readily available from most component stockists.

With all of the internal wiring completed (the temperature sensors should not have been hooked up at this stage) and checked, apply power to the unit and note that regardless of the display mode selected, the display should be flashing on and off at one second intervals. This flashing is a mains failure indicator, and will occur after every power failure to the clock.

The flashing can be stopped by setting the function select switch into the time position and then pressing either of the two time-setting buttons on the rear panel.



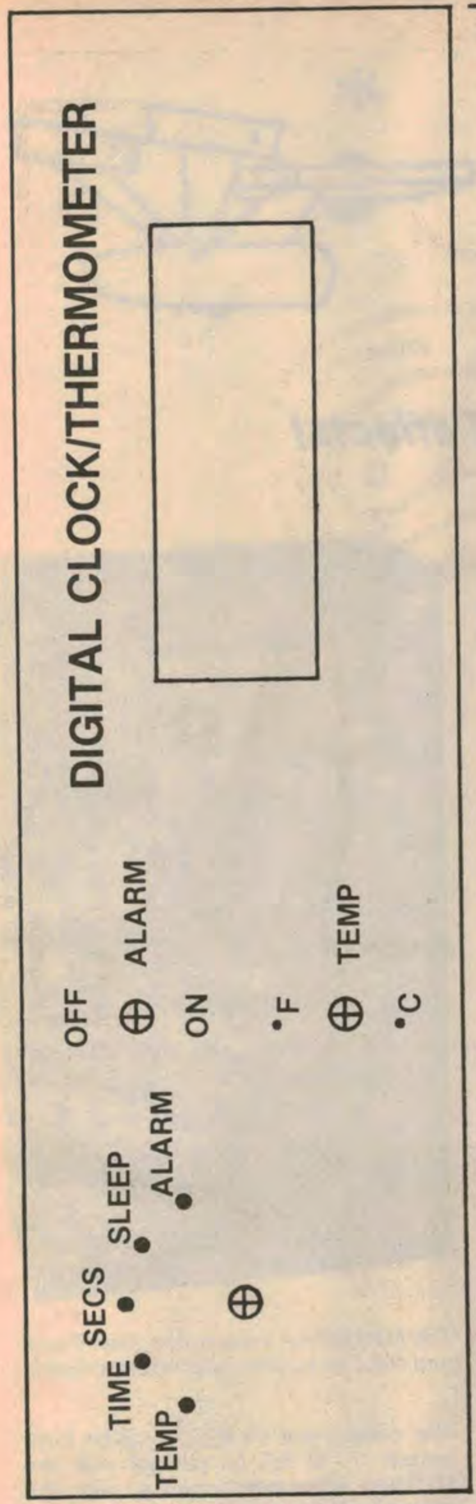



*Above is the full-size artwork of the PC board while below is a photo showing the wiring behind the front panel. In our prototype only one pole of the selector switch was used but two poles will be required if you wish to use this switch to select more than one temperature sensor.*

Go through each of the mode selections and make sure that the display comes up with the correct information corresponding to the selected mode. If not, then chances are that two of the mode selection wires have been transposed at the switch connections. The only setting that will give a nonsensical reading at this stage will be the temperature mode. It should read −40° in either F or C modes.

Connecting the battery will prevent the display from flashing when the power is interrupted. If your module is MA1026A, B or C you will have to add the diode and 0.1μF metallised polyester capacitor (in place of a link) shown arrowed in a photograph accompanying this article. It is necessary to set the 4.7MΩ trimpot for exactly 20Hz from the backup oscillator. This frequency can be measured at pin 26 of the module using a frequency meter or CRO, or it can be set by trial-and-error.

Now check that the dimmer circuit is functioning correctly. This can be done by exposing the LDR to bright light and noting that the display is bright. Now cover the LDR with your hand and note that the display dims.




*This is the full size artwork for the front panel. Note that there is a discrepancy in the order of functions selected between this artwork and the photograph on p42. Unit is easier to operate with "temperature" adjacent to "time".*

If all of these tests prove positive, remove the plug from the wall and mount and connect the temperature sensor.

To calibrate the temperature sensor you will require an accurate thermometer and a fan. Place the thermometer and temperature sensor so that they both receive the same draft from the fan and then adjust the 220Ω trimpot to obtain a reading on the display which agrees with the thermometer. This will involve a number of trial-and-error steps because of the slow update time of the temperature display.

If you find that the trimpot does not give enough range for adjustment (this is possile as no two current sources have absolutely identical characteristics) then place a 1.8kΩ resistor in the position on the board labelled Rp. This will reduce the overall value of the trimmer resistance. If on the other hand, the value of the resistance needs to be increased, then substitute a 10Ω resistor for the 2.7Ω. Any adjustment of values required should be quite small.

An external transistor radio can be controlled by the clock using the sleep timer output socket. Here the positive supply from the battery in the radio would be switched by the transistor on board the clock module. The positive of the radio supply and the positive of the clock supply are connected together to form the common connection.

Well, that's just about it. The rest is up to you.

## PARTS LIST:

*1 Pac Tec enclosure 205mm W × 57mm H × 159mm D*
*1 National Semiconductor clock module, type MA1026ALR*
*1 transformer Selectronics type X1132, DSE M-2824 or similar*
*1 printed circuit board, 172 × 120mm (81c19)*
*1 single-pole, 6-position rotary switch*
*3 single-pole double-throw miniature toggle switches*
*1 3.5mm earphone socket*
*1 polarised 2-pin DIN socket*
*1 50mm diameter loudspeaker*
*3 momentary contact pushbutton switches*
*1 type 216-9 volt battery and clip to suit (optional, see text)*
*1 4.7MΩ miniature trimpot*
*1 220Ω miniature trimpot*
*1 BC547 NPN transistor*
*1 1N4001 diode (see text)*
*1 1N4148 diode*
*1 10μF/16VW aluminium electrolytic capacitor*
*1 0.1μF metallised polyester capacitor (see text)*
*1 ORP-12 light dependent resistor*
*1 × 100kΩ, 1 × 10kΩ, 1 × 2.7Ω (all ¼W, 5%) resistors*
*1 LM334 programmable current source*
*1 mains cord and plug assembly*
*1 2-way mains-rated terminal block*
*1 cord-grip grommet*
*Hookup wire, solder, screws, nuts etc.*